A 900MHz HBT Power Amplifier MMICs with 55% Efficiency, at 3.3 V Operation

H. Asano, S. Hara, and S. Komai.
VLSI Development Laboratories, Tenri-IC Development Group, Sharp Corporation
2613-1 Ichinomoto-cho, Tenri, Nara 632 JAPAN
TEL:+81-743-65-2486, FAX:+81-743-65-2487, e-mail:asano@mic.tnr.sharp.co.jp

ABSTRACT

A 3.3 volt GSM class V power amplifier MMIC has been developed by using AlGaAs/GaAs HBTs and flip chip bonding technology. The amplifier has an output power of 32dBm and a power added efficiency of 55%. The HBT amplifier inherently requires no negative bias and has very low leak current, 2nA. The MMIC is assembled to small and low profile package (6.35×6.35×1.05mm).

INTRODUCTION

There are lots of activities to realize low operation voltage and high efficiency power amplifiers for small and light mobile communication terminal application, by using various kinds of technologies, such as Si devices or GaAs devices, hybrids or MMICs (1-4). Now it seems that GaAs MMICs are widely accepted in the market compared to Si device and/or hybrid module from the size and performance points of view. Furthermore, system engineers do not want to use negative-bias voltage. Therefore, GaAs MESFET MMICs with negative bias generator or GaAs MMICs using E-mode FETs become popular (3,4). However, they basically require a MOSFET switch between battery and power supply terminal of MMIC to cut off the leak current during waiting time. We have been developing mobile communication MMICs by using AlGaAs/GaAs HBT technologies
which can realize positive bias operation and does not require the switch because of its negligible leakage current (5,6). In this paper, we will discuss our newly developed power amplifier MMIC that is designed primary for GSM class V applications.

DESIGN

Our MMIC is composed of AlGaAs/GaAs HBTs, spiral inductors, MIM capacitors, and resistances using the base layer. The HBT unit size is 6.4•m×20•m and it has n-$Al_xGa_{1-x}As$ integrated emitter ballast resistance to prevent from the current crush (6). The spiral inductor has the metal thickness of 9•m to reduce DC resistance, and we have modeled it by considering skin effect as a function of total length (7). With regard to the assembly technology, we use FCB (Flip Chip Bonding) technology to reduce both thermal resistance and grounding inductance, and the substrate does not have VIA hall.

The circuit schematic is shown in figure1. We use 48 unit HBT for power stage, 12 unit cascode connected HBT for a driver stage to minimize the output power during the off–burst, which is defined as the term, “isolation”. By using this method, the isolation has been improved 6dB compared to common source two stage amplifier. Feed-back amplifier is employed in the driver stage for stable operation. 3dB attenuator is inserted at input port for wide band, low input VSWR.

We use DC amplifier in the power stage because the control current must be low enough from system requirement (8). However, that configuration requires 2.6V to turn on the HBT, and the control curve would be very steep because the maximum control voltage is not high enough in 3V system. To realize low control current and gentle slope simultaneously, the control voltage supplies both directly to the base of the output HBT and one of the DC driver amplifier in this design. The output matching circuit can not be include on the chip

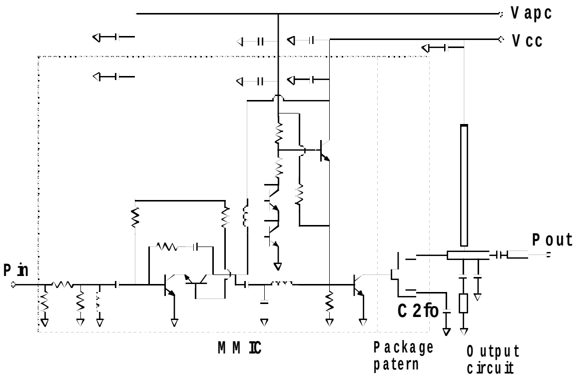

Fig. 1 Circuit schematic of the power amplifier.

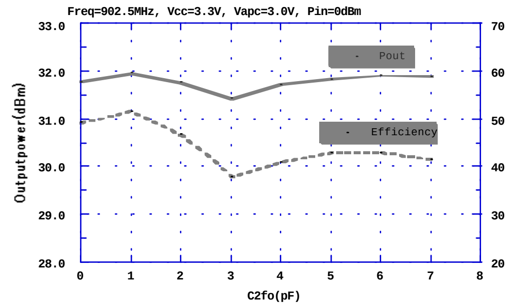

Fig. 2 Output power and efficiency versus the capacitance value.

because the line loss results large voltage drop. The MMIC is assembled to Al_2O_3 package by using FCB technology (6). The collector of the output HBT is connected to the pad on the Al_2O_3 substrate and the pattern on the substrate separates toward two output pins of the package, as shown in figure 1. One pin is for fundamental wave matching and the other is for the 2nd harmonics treatment. By separating these terminals just after collector of the HBT, 2nd harmonics and fundamental wave can control separately. High efficiency is obtained by tuning reflection co-efficient of the 2nd harmonics (9).

The output matching circuit is realized on printed circuit board. Parameters of the output matching circuit were determined by the results obtained from load-pull measurements and harmonic balance simulations in order to design for high efficiency. The reflection co-efficient of the 2 nd harmonics is determined by capacitance value, C2fo, which has been tuned experimentally. Output power, efficiency versus capacitance value is shown in figure2. The maximum performance is obtained at the C2fo value of 1pF.

RF CHARACTERISTICS

Figures 3 to 6 show the electrical performance of the MMIC in which the output circuit is designed for the GSM classV power amplifier. Figure 3 shows the power control characteristics at 902.5MHz. The single positive voltage supply, Vcc, is 3.3 V and the input power, Pin, is 0dBm. The output power ramps up from the control voltage, Vapc, of 1.3 V, and increases smoothly and monotonously as the control voltage increases. 32dBm output power and 55% efficiency is obtained at Vapc=3V. Figure 4 to 6 show frequency characteristics of the MMIC. Vcc is 3.3 V, Pin is 0dBm, and Vapc is 3 V. Over 32dBm output power and 55% efficiency are realized in the GSM band, between 890MHz and 915MHz. In addition, the 2 nd and 3 nd harmonic distortion are less than –40dBc and the control current is less than 2.4mA along with input VSWR of 1.7:1.

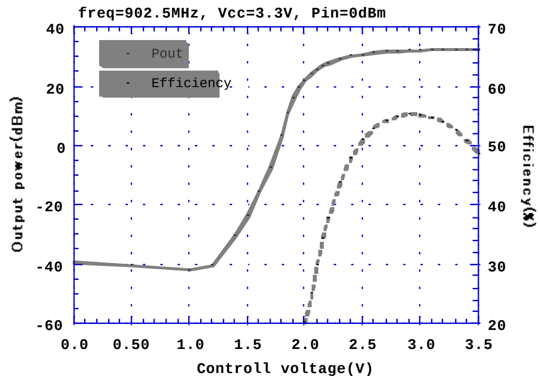

Fig. 3 Control voltage dependency of the power amplifier.

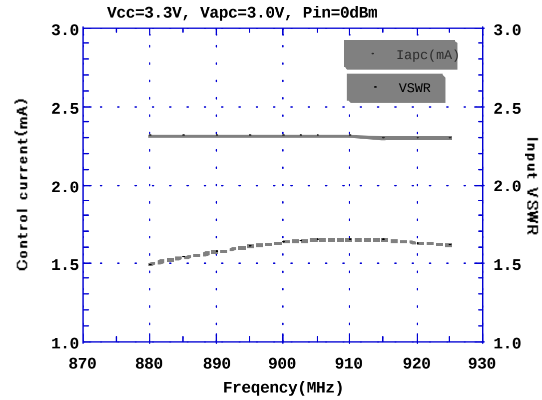

Fig. 6 Frequency characteristics of control current and input VSWR.

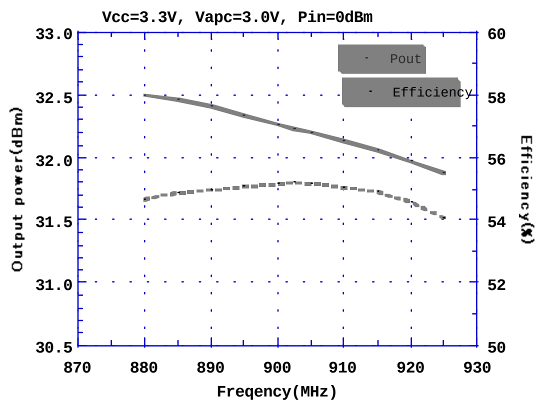

Fig. 4 Frequency characteristics of output power and efficiency.

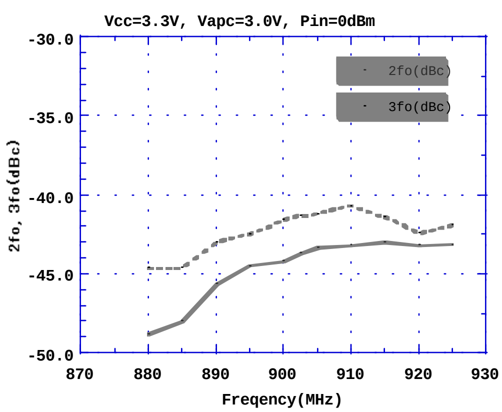

Fig. 5 Frequency characteristics of 2 nd and 3 rd harmonics.

Figure 7 shows Vcc dependency of the output power and efficiency at Pin=0dBm and Vapc=3.4V which is typical value for 4.8V system. At Vcc=4.7V, output power of 35dBm and efficiency of 50% is obtained. This means the MMIC shows good performance also for GSM class IV application under Vcc=4.7V. Furthermore, even at 3V, this power amplifier can output more than 31.5dBm. The leakage current is less than 2 nA at Vcc=3.3 V and 8 nA even at Vcc=6V. It is negligible and does not require the switch on the power supply line, which adds some cost and area. Furthermore, this MMIC can use various applications in UHF band such as DAMPS or analogue cellular, by changing only output circuit and Vapc voltage due to wide-band input matching.

The package size is only 6.35×6.35×1.05mm. This low profile characteristic is attractive to realize a thin terminal such as PCMCIA card.

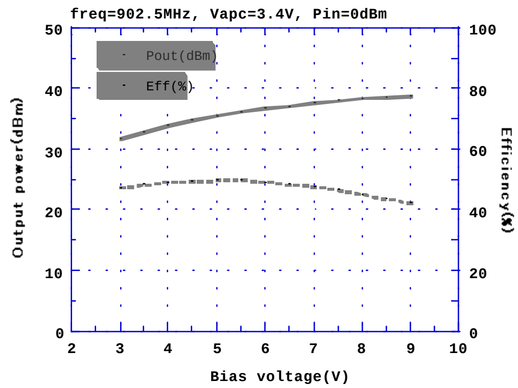

Fig. 7 Bias voltage dependency of the power amplifier.

CONCLUSION

The developed MMIC has very attractive performance for portable mobile communication equipment as follows:

1) Low operation voltage (3.3 V),
2) High efficiency (55 %),
3) Positive bias operation,
4) Extremely low leak current (2nA),
5) Small and low profile package (6.35×6.35×1.05mm).

ACKNOWLEDGEMENT

We would like to acknowledge Mr. Yamamoto for conducting wafer process and Mr. Konishi for conducting assembly process. We would also like to acknowledge Mr. Ashida and Mr. Yoshimasu for their continuous suggestion and encouragement.

REFERENCES

[1] C. Dragon, et al., “A Silicon MOS Process for Integrated RF Power Amplifiers,” *IEEE 1996 Microwave and Millimeter-wave Monolithic Circuits Symposium Digest*, pp.189-192.

[2] S. Makioka, et al., “A Miniaturized GaAs Power Amplifier for 1.5 GHz Digital Cellular Phones,” *IEEE 1996 Microwave and Millimeter-wave Monolithic Circuits Symposium Digest*, pp.13- 16.

[3] W. Abey, et al., “An E-Mode GaAs FET Power Amplifier MMIC for GSM Phones,” *1997 IEEE MTT-S Digest*, pp.1315- 1318.

[4] Barak Maoz,“GaAs Integrated Power Amplifier Help Answer Market Demand,” *Wireless Design & Development*, 1997.9, pp.21-24.

[5] T. Yoshimasu, et al., “A Low Distortion and High Efficiency HBT MMIC Power Amplifier with a Novel Linearization Technique for•/4 DQPSK Modulation,” *1997 GaAs IC Symp. Digest*, pp.45-48.

[6] S. Hara, “HBT Power Amplifier MMICs for Cellular Phone using FCB Technology,” *MWE’96 Microwave Workshop Digest*, pp. 61-66.

[7] M. Furukawa et al, “The Equivalent Circuit Modeling of Spiral Inductors inculuding the Skin Effect,” *1993 IEICE Spring Conference*, C-115, March 1993. (in Japanese)

[8] K. Sakuno et al, “A 3.5W HBT MMIC Power Amplifier Module for Mobile Communications,” *1994 Microwave and Millimeter-wave Monolithic Circuits Symposium Digest.*, pp. 63-66.

[9] T. Nojima et al, “High Efficiency Transmitting Power Amplifiers for Portable Radio Units,” *IEICE Trans.* vol. E74, No.6, pp.1563-1569, June 1991.